Coastal Oil & Gas Corporation

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September 24, 1980

Department of Energy
Nevada Operations Office
P. 0. Box 14100
Las Vegas, Nevada 89114

Attn: Mr. J. B. Cotter

RE: DOE/ET/12060-1
Final Report on: Massive Hydraulic Fracturing in the Natural Buttes Unit
Uintah County, Utah

Dear Mr. Cotter:

Please refer to your June 26, 1980 letter to Mr. Kim Smith, above subject.

Please find attached final report on "Massive Hydraulic Fracturing in the Natural Buttes Unit, Uintah County, Utah". The changes which you requested be made to the initial submittal of the subject report have been incorporated into this report. This is the final report of work performed for Phase I through VIII under Department of Energy contract No. DE-AC08-76-ET-12060.

Please note that the text of this report comments that the MHF project at Natural Buttes Unit has been completed with the exception of Phase IX, specifically the final core analysis of cores taken at the CIGE No. 21-15-10-22. After the report was put into final form, the core analysis on CIGE 21-15-10-22 was received from Terra Tek, Inc. With the attachment of the core analysis on CIGE 21-15-10-22 the report on Massive Hydraulic Fracturing in the Natural Buttes Unit under DOE contract No. DE-AC08-76-ET-12060 is complete.

Sincerely,

Terry L. Jackson

Terry L. Jackson
Production Engineer

TLJ/ma

Attachments

xc: Frank Midkiff
Miles Reynolds

Form DOE 426
(2/75)
ERDAM3201

U. S. DEPARTMENT OF ENERGY
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2. Subject Category No. UC-92

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- [X] a. Scientific and Technical Report
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Coastal Oil & Gas Corp., Denver, Colorado

15. Signature
Terry L. Jackson

16. Date
September 24, 1980

DOE/ET/12060-1
Dist. Category UC-92

MASSIVE HYDRAULIC FRACTURING IN THE NATURAL BUTTES UNIT UINTAH COUNTY, UTAH

Final Report
(Phases I - VIII)

Kim L. Smith
Terry L. Jackson

Coastal Oil & Gas Corporation
(Formerly Gas Producing Enterprises, Inc.)
P. 0. Box 749
Denver, Colorado 80201

April, 1980

PREPARED FOR
U. S. DEPARTMENT OF ENERGY

Contract No. DE-AC08-76ET 12060

Printed in the United States of America

Available From: National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy - $6.00
Microfiche - $3.50

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MASSIVE HYDRAULIC FRACTURING IN THE NATURAL BUTTES UNIT, UINTAH COUNTY, UTAH

by Kim L. Smith, Coastal Oil & Gas Corporation (formerly Gas Producing Enterprises, Inc.), and Terry L. Jackson, Coastal Oil & Gas Corporation.

This is the final report of work performed for phases I through VIII under Department of Energy Contract No. DE-AC08-76ET 12060.

ABSTRACT

The Massive Hydraulic Fracturing (MHF) project in the Natural Buttes Unit has been completed with the exception of phase IX, specifically the final core analysis report on cores taken at the CIGE No. 21-15-10-22. Terra Tek, Inc. has projected a mid-May completion on that report, and it will be forwarded under separate cover. The results of the program indicated poor economics for the justification of massive hydraulic fracturing, but sufficient information was obtained on fluids and proppants to permit standardization of the fracture treatments in the Wasatch/Mesaverde formations of the Natural Buttes Unit. --

Materials and equipment selection has improved with experience in massive hydraulic fracturing with regard to the actual operation, but evaluation techniques for determining fracture growth, in situ rock-fluid interaction, and in situ rock mechanics with regard to fracturing have not developed with industry experience. The nature of the completions (i.e. multi-zone with limited, if any, selective testing) does not permit evaluation of the fracture treatments with bottom-hole pressure buildup analysis.

INTRODUCTION

Drilling began in Bitter Creek Field, Uintah County, Utah in the early 1940's. The early wells were completed in several prospective zones in the Wasatch and Mesaverde formations based on criteria such as clean gama ray, porosity development, and drilling shows. Stimulation, if necessary, was restricted to 10,000 - 20,000 gallon acid jobs or 15,000 - 35,000 gallon fracture treatments with 15,000 - 30,000 pounds of sand. This type of stimulation in the usually tight Wasatch and Mesaverde sands had the effect of removing wellbore damage caused by the drilling operations, but did very little to increase recoverable reserves.

The Natural Buttes Unit was formed in the Bitter Creek Field on January 5, 1968; and Gas Producing Enterprises, Inc. (GPE) began operations within the unit in 1969. Completion procedures remained similar to the early completions until work began in Sept. 1976 under Department of Energy Contract No DE-AC08-76ET 12060. This contract outlined a program to perform nine MHF treatments over a two-year period for the purpose of determining a cost-efficient method of increasing reserves in low-permeability sands. Figure 1 is a unit map of the Natural Buttes Unit with the nine wells highlighted, and Figure 2 is a typical porosity log showing tested interval in CIGE No. 21-15-10-22. Figures3 through 10 are performance curves for the wells involves in the program.

All work under this contract has been completed with the exception of core analysis work being performed by Terra Tek, Inc under phase V. Total cost of the program was $6,002,722.21 of which the Department of Energy paid $1,976,080.11 and GPE paid $4,026,642.10.

This paper summarizes the work performed under the contract, updates individual well performance, and presents conclusions along with current procedures.

DISCUSSION

The nine MHF treatments performed in this program were designed with variations in fluid viscosity, fluid volumes, and proppant sizes in order to determine the optimum method of releasing trapped reserves in the low permeability - low porosity Wasatch and Mesaverde sands.

Crosslinked or viscous fluids were used to obtain "vertical suspension" proppant distribution as opposed to "equilibrium banking" distribution obtained with this on non-crosslinked fluids.

Fluid volumes were varied dependent on whether a multiple entry (staged) job or a limited entry job was designed, and refined and unrefined guars (gelling agents) were used to determine the effects residue had on well performance after treatment and cleanup.

Proppant concentrations and sizes were varied with no observed effects.

The following discussion summarizes the individual MHF treatments and presents results obtained through post-frac studies and performance. All frac dates are shown on the attached performance curves. All GPE costs shown include drilling and completion costs.

PHASE I - NATURAL BUTTES NO. 18

Natural Buttes Unit No. 18 was perforated in 18 zones over the interval 6490' - 8952', with a total of 72 holes. The well was treated with 9,000 gallons of 15% HCl, 695,000 gallons of 2% KCl gelled with 50 pounds / 1,000 gallons of low residue guar gum and crosslinked for viscosity, 100,000 pounds of 40/60 sand, and 1,380,000 pounds of 20/40 sand pumped in nine stages. Production prior to the frac had averaged 10-20 MCFD, and following a sand cleanout approximately three months after the frac job, the well was completed for 1326 MCFD.

Total costs of the frac and subsequent cleanout was $814,827.41 of which the Department of Energy paid $175,000.00, and GPE paid $639,827.41

Cumulative production through January 1, 1980, was 821.8 MMCF. Figure 3 is a performance curve for the subject well.

PHASE II - NATURAL BUTTES UNIT NO. 19

This well was treated with two fracs in 19 zones in the Mesaverde formation over the interval 7220' - 9664'. A total of 76 perforations were opened in the 19 zones. The first frac treated nine zones in the interval 8909' - 9664' with 5,000 gallons of 15% HCl, 5,586 gallons of 2% KCl water gelled with 20 pounds / 1,000 gallons of high residue guar gum, 269,260 gallons of 2% KCl water (40 - pounds gel, high residue guar gum), 61,000 pounds of 100 mesh sand, and 363,000 pounds of 40/60 sand pumped in five stages. A total of 435,000 SCF N_2 was used throughout the job.

Radioactive tracer sand was used to permit post-evaluation of the frac. A gamma ray-temperature log run after the frac indicated two lower zones covered with sand, but also showed that the seven upper zones were fraced successfully, that the bordering shales contained the frac in each zone, and that no channelling occurred.

The second frac treated the interval 7200' - 8676' (10 zones) with 6,500 gallons of 15% HCl, 358,302 gallons of 2% KCl (30 pounds gel, high residue guar gum), 72,576 pounds of 100 mesh sand, and 711,651 pounds of 40/60 sand pumped in seven stages with 555,000 SCF N_2.

A gamma ray log run after five months due to delays caused by mechanical problems again indicated that each zone was treated, and that the treatment remained in the zones.

The well was completed for 161 MCFD following a total cost for the two frac jobs of $683,755.03. The Department of Energy paid $150,000.00 and GPE paid $533,755.03. Cumulative production through January 1, 1980, was 27.4 MMCF. Figure 4 is the performance curve for the well.

PHASE III - NATURAL BUTTES UNIT NO. 14

Natural Buttes Unit No. 14 was an old well that had produced only 51.0 MMCF since completion in October, 1974 after treatment with 10,000 gallons 15% HCl until MHF treatment on March 15, 1977. The well was opened in 15 zones from 6646' - 8004' with 60 total holes. The treatment consisted of 8,000

gallons of 15% HCl, 32,000 gallons of 2% KCl pre-pad, 544,000 gallons of 2% KCl water gelled with 50 pounds / 1,000 gallons of crosslinked, low residue gel, 40,000 pounds of 40/60 sand, and 1,053,000 pounds of 20/40 sand pumped in eight stages separated by ballsealers. Production increased to approximately 700 MCFD after the frac, as shown on the performance curve included as Figure 5; and cumulative production through January 1, 1980, since the frac was 406.2 MMCF.

The Department of Energy paid 50% or $121,697.17 of the total cost of $243,358.25 for the frac.

PHASES IV - NATURAL BUTTES UNIT NO. 20

This well was completed with the limited entry technique, with only 26 perforations in seven zones over the interval 8498' - 9476'. Flow rates following perforating and acidizing ranged form 75 MCFD to 150 MCFD. The well was fraced with 2,600 gallons of 7½% HCl, 10,000 gallons of 2% KCl water, 309,000 gallons of 2% KCl water with 50 pounds / 1,000 gallons low residue guar gum gel crosslinked for viscosity, 56,000 pounds of 100 mesh sand, 745,000 pounds of 40/60 sand, 25,000 pounds of 20/40 glass beads, and radioactive tracer sand. The well was completed for 1100 MCFD and had produced 449.1 MMCF through January 1, 1980. Figure 6 is a performance curve for the subject well.

A gamma ray log run after cleanup indicated that all zones were treated, no channelling occurred, and the frac was contained by barrier shales.

Total cost of the frac was $822,155.56, of which the Department of Energy paid $125,435.89, and GPE paid $696,719.67.

PHASE V - NATURAL BUTTES UNIT NO. 21 (CIGE 21-15-10-22)

Phase V includes drilling, coring and testing of six zones in the Mesaverde formation of the subject well. Production tests on the six zones ranged from water and gas too small to measure to 100 BWPD with gas too small to measure. All cored intervals and tested intervals with test results are shown on Figure 2.

Terra Tek, Inc. has scheduled completion of the core analysis final report for mid-May, 1980. That report will be submitted under separate cover.

Total cost of Phase V was $639,272.55, of which the Department of Energy paid $575,345.29, and GPE paid $63,927.26.

PHASE VI (A) - NATURAL BUTTES UNIT NO. 9

Natural Buttes Unit No. 9 was completed in May, 1972 over the interval 5661' - 8934' with 56 perforations. The 42 zones opened in this interval were fraced with 7,500 gallons of HF acid, 32,634 gallons of 2% $CaCl_2$, and 21,500 pounds of 20/40 sand during initial completion, resulting in initial production of 875 MCFD. This well produced 459.0 MMCF from initial sales unitl the MHF was performed on March 27, 1978.

The MHF treatment consisted of 7,000 gallons of 7½% HCl, 35,500 gallons of 2% KCl water pad slicked with 10 pounds / 1,000 gallons high residue guar gum, 56,600 gallons of 2% KCl water with 60 pounds / 1,000 gallons of high residue guar gum, 258,000 gallons of 40 pounds / 1,000 gallons of high residue guar gum, 28,000 pounds of 100 mesh sand, 525,000 pounds of 40/60 sand, 2,200 pounds of 50/50 unibeads, and 110 tons of CO_2 pumped in twelve stages. Cumulative post-frac production was 218.4 MMCF through January 1, 1980. Figure 7 is a performance curve for the well.

The Department of Energy paid $167,673.99 of the total cost of $223,685.32 for the MHF treatment of Natural Buttes Unit No. 9. GPE paid $55,921.33.

PHASE VI (B) - NATURAL BUTTES UNIT NO. 22

The limited entry technique was used again on Natural Buttes Unit No. 22, where twenty zones were opened with 35 perforations over the interval 6838' - 8550'. Flow rates averaged 175 MCFD prior to the fracture treatment. The MHF treatment consisted of 3,500 gallons of 7½% HCl, 12,000 gallons of 2% KCl water, 478,758 gallons of 2% KCl gelled with 60 pounds / 1,000 gallons of low residue guar gum crosslinked for viscosity, 60,000 pounds of 100 mesh sand, 1,066,000 pounds of 40/60 sand, and 25,000 pounds of 20/40 glass beads. Total production through January 1, 1980, was 51.1 MMCF. The well has been shut-in for the past 12 months due to high water production. A performance curve for the well is shown as Figure 8.

Phase VI (B) costs were $837,768.14 of which the Department of Energy paid $207,360.49, and GPE paid $630,407.65.

PHASE VII - CIGE 23-7-10-22

CIGE 23-7-10-22 was completed in ten zones in the Wasatch with 20 perforations from 5080' - 6294'. This limited entry completion was acidized with 4,000 gallons of 7½% MSR prior to fracturing and flowed approximately 400 MCFD. The frac consisted of 240,000 gallons of 40-pound low residue, crosslinked gel, 90,000 pounds of 100 mesh sand, 135,000 pounds of 40/60 sand, 205,000 pounds of 20/40 sand, and 40,000 pounds of 10/20 sand.

Total cost of Phase VII was $706,764.20. The Department of Energy paid $61,329.79, and GPE paid $645,434.41.

The well was completed for 800 MCFD after cleanup and had produced 276.5 MMCF through January 1, 1980. Figure 9 shows the five-month performance for the well.

PHASE VIII - CIGE 2-29-10-21

Phase VIII total costs were $1,031,135.65. The Department of Energy paid $392,165.49, and GPE paid $638,970.16. These costs included two fracs on separate intervals and a subsequent sand cleanout of the upper intervals.

CIGE 2-29-10-21 was initially perforated in eleven zones, with 22 perforations from 9237' - 9653', and was acidized with 3,000 gallons of 15% MSR. These zones tested gas too small to measure prior to a frac consisting of 195,000 gallons of 2% KCl gelled with 30-40 pounds / 1,000 gallons of high residue guar gum, 30,000 pounds of 100 mesh sand, and 140,500 pounds of 40/60 sand. Subsequent cleanup operations recovered only water, and a CIBP was set to isolate the perforations.

The second set of perforations covered 14 zones with 24 holes from 7251' - 8774'. These perforations were acidized with 4,500 gallons of 7½% HCl and produced approximately 30 MCFD prior to fracturing. The frac consisted of 722,000 gallons of 2% KCl with 40 pounds / 1,000 gallons of high residue gel, 78,000 pounds of 40/60 sand, and 1,176,000 pounds of 20/40 sand with radioactive tracer sand throughout the job. After an overnight shut-in period, the well was opened up completely dead, and cleanup operations found sand 12 feet below the surface. Initial producing rates following cleanup were 500 MCFD.

A gamma ray log run over the upper perforations after the frac indicated that all zones were fraced, and that the frac was contained by barrier shales with the exception of the interval 8532' - 8674', where the tool detected radioactive sand throughout the interval.

This well had produced 10.0 MMCF through January 1, 1980, as shown on Figure 10.

CONCLUSION

The Wasatch and Mesaverde formations are typically lagoonal or deltaic deposits with some channel sands, and the sands that develop within these formations are lenticular fine-grained dirty sands with low porosity and permeability. Problems that arise in evaluation of potentially productive zones, such as the discontinuous nature of the sands making correlation virtually impossible, and log-derived values of water saturation being unreliable, might obscure some of the conclusions that have been made based on the results of MHF program. This was observed in CIGE 21-15-10-22 and CIGE 2-29-10-21, where production tests before and after stimulation failed to establish production.

High residue guar gum was used as the gelling agent for the MHF treatments on Natural Buttes Unit No. 19, Natural Buttes Unit No. 9, and CIGE 2-29-10-21. These guar gums were unrefined and contained approximately 10% residue by volumes versus approximately 1% residue by volume in the low residue or refined guar gums. Results of the three fracs ranged from a low-volume well at Natural Buttes Unit No. 19 to quadrupled production of Natural Buttes Unit No. 9 Results at CIGE 2-29-10-21 were disappointing with initial production rates of approximately 500 MCFD. Performance for the single month of unrestricted production to date was considerable lower at approximately 100 - 150 MCFD.

Two of only three wells treated with fluids gelled with high residue guar gum were completed as poor producers, indicating the possibility of formation damage due to the residue. Although there was a lack of field data obtained to support this conclusion, results of the fluid-rock interaction

tests being run on the CIGE 21-15-10-22 core by Terra Tek, Inc. also indicate moderate to severe formation damage. Final results of the core analysis will be submitted in May 1980.

A second factor that was varied was fluid viscosity. Crosslinking agents were added to provide viscosity to carry the proppant and provide for "vertical suspension" distribution of the proppant instead of "equilibrium banking" distribution that is provided by thin or non-crosslinked fluids. A problem with control develops when considering that all low residue guar gum gel were crosslinked in this experiment and that all high residue guar gum gells remained non-crosslinked. The three wells discussed above could be discussed again with regard to fluid viscisity. However, it is not possible to separate the effects of residue and viscosity in the field data.

All remaining fracture treatments performed during this program used low residue, crosslinked gel for the fracturing fluid. Natural Buttes Unit No. 22 is the only marginal well that was fraced with a low residue, guar gum gel crosslinked for viscosity. Initial-production rates of approximately 600 - 700 MCFD were affected by high water production and eventually declined when water production increased to create disposal problems. This well has been shut-in for over twelve months.

Proppant sizes of 20/40 mesh and 40/60 mesh have no observable effect on well performance in the tight Wasatch and Mesaverde sands. Sand crushing does not appear to be a problem. Glass beads were used in three fracs, and no sustained production increase has been observed in these wells versus those wells where only sand was used as a proppant. Some 100 mesh sand was used during the program as a fluid loss agent, but no adverse or beneficial effests were observed.

Radioactive sand was used in three fracs, and post-frac gamma ray log indicated that all zones were fraced in the two "staged" fracs and the one "limited entry" frac. The barrier shales apparently contained the frac within the zones in each frac on Natural Buttes Unit No. 19. However, radioactive sand was detected over a 142-foot interval after the frac on CIGE 2-29-10-21. The shales contained the frac in the remaining zones. A doubtful cement job over washed-out hole was concluded to have permitted the frac to communicate in the 142-foot interval.

Pre-planning for a MHF treatment is necessary with regard to hole size and wellbore equipment. Casing and/or tubing must be sized and graded to enable the high rates necessary in a limited entry treatment and the high pressures that occur in a staged treatment. Location size and layout is also important for proper logistics.

Gas Producing Enterprises, Inc. has remained active in the Natural Buttes Unit, but is now drilling and completing in the Wasatch due to poor economics that resulted from drilling to the deeper Mesaverde formation.

Limited entry completions are used almost exclusively now with the fracture treatments designed on a rule-of thumb of approximately 35,000 pounds of 20/40 mesh sand per zone. The 100 mesh sand is no longer used. Pump rates average approximate1 40 BPM for low residue, crosslinked fluids with sand concentrations of one to four pounds per gallon.

ACKNOWLEDGMENT

Additional information can be obtained from the references listed at the end of this report. These include papers presented at previous Department of Energy Symposiums, monthly technical reports, and an article published in an industry journal.

Technical and field support during this project was provided by the Department of Energy; F. R. Midkiff, Coastal Oil & Gas Corporation; K. E. Oden, Coastal Oil & Gas Corproation; J. A. Short, Coastal Oil & Gas Corporation; and W. E. Spencer, The Coastal Corporation.

The author would like to thank the Coastal Corporation for the opportunity to prepare this report.

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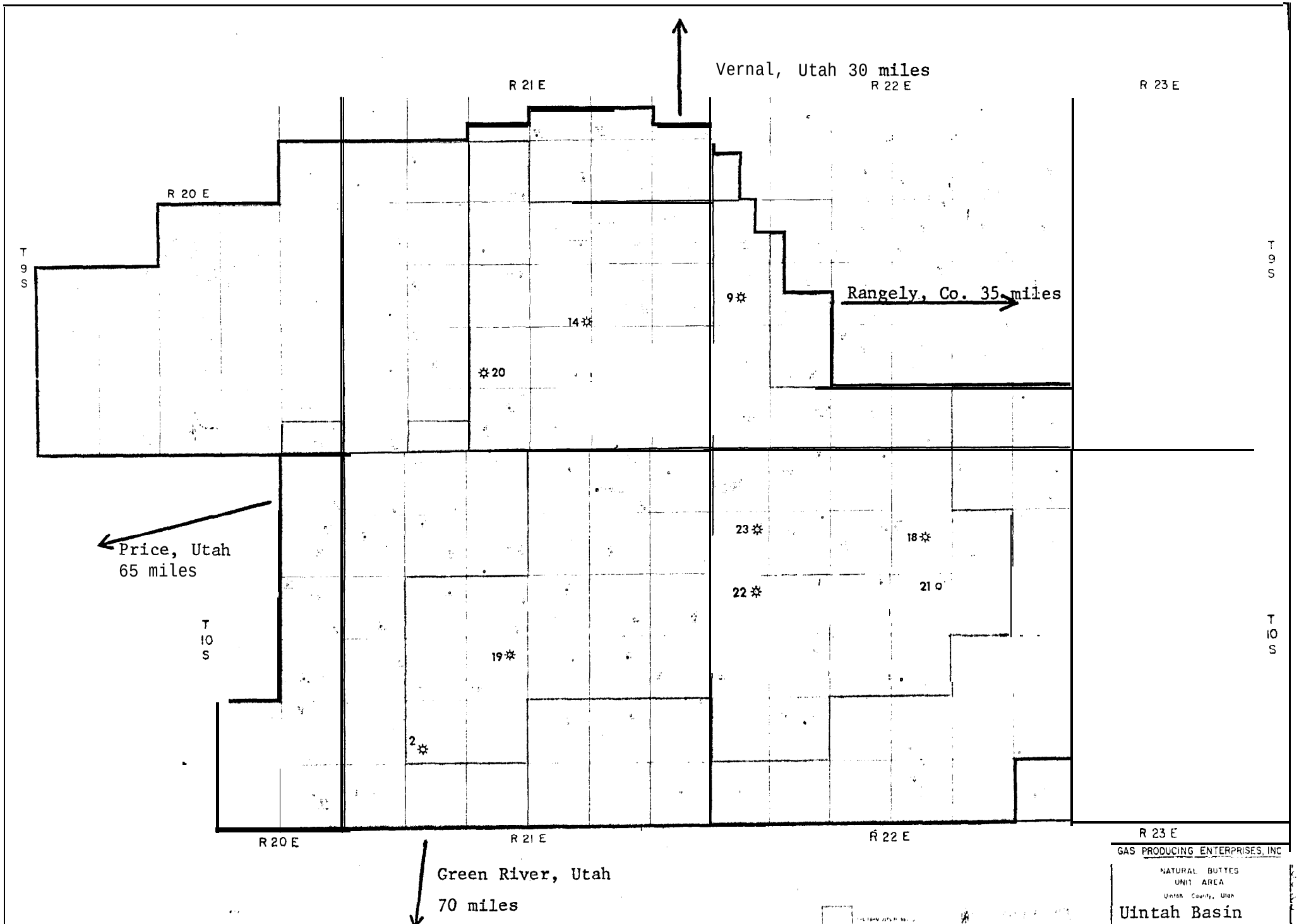
Vernal, Utah 30 miles
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R 22 E
R 23 E
R 20 E
T 9 S
T 10 S
Rangely, Co. 35 miles
Price, Utah
65 miles
Green River, Utah
70 miles
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GAS PRODUCING ENTERPRISES, INC
NATURAL BUTTES
UNIT AREA
Uintah County, Utah
Uintah Basin

COMPANY CIG EXPLORATION, INC.

WELL NATURAL BUTTES # 21, 15-10-22

FIELD BITTER CREEK, NAT. BUTTES UNIT

COUNTY UINTAH STATE UTAH

LOCATION: SEC. 15 TWP. 10S RANGE 22

API SERIAL NO.

Other Services: DLL-MSFL-GR BHC-GR; LSS HDT; TAPING

Elev.: K.B. 4868'
D.F.
G.L. 4850'

Permanent Datum: GL Elev.: 4850'
Log Measured From KB 18 Ft. Above Perm. Datum
Drilling Measured From KB

Date	11-10-77
Run No.	ONE
Depth—Driller	8788
Depth—Logger	8788
Btm. Log Interval	8787
Top Log Interval	2530
Casing—Driller	9 5/8 @ 2531
Casing—Logger	2530
Bit Size	8"
Type Fluid in Hole	SALT MUD
Dens. / Visc.	12.6 / 44
pH / Fluid Loss	11.0 / 10.2ml
Source of Sample	FLOWLINE
Rm @ Meas. Temp.	.072 @ 58 °F
Rmf @ Meas. Temp.	.055 @ 58 °F
Rmc @ Meas. Temp.	.11 @ 58 °F
Source: Rmf / Rmc	M / C
Rm @ BHT	.024 @ 180°F
Circulation Stopped	0200
Logger on Bottom	1330
Max. Rec. Temp.	180 °F
Equip. / Location	7634 / VERNAL
Recorded By	LGUTNER
Witnessed By Mr.	[illegible]

FOLD HERE

The well name, location and borehole reference data were furnished by the customer.

RUN NO.	ONE				Type Log	Depth
Service Order No.	01964					
Fluid Level	FULL					
Salinity, PPM CL.	---					
Speed - F.P.M.	30					
EQUIPMENT DATA						
Dens. Panel	694					
Dens. Cart.	661					
Dens. Skid.	1074					
Dens. Sonde	183					
Dens. Source	3215					
Dens. Calibrator	1033					
Neut. Panel	415					
Neut. Cart.	421					
Neut. Source	431					
Neut. Calibrator	475					
GR Cart.	1463					
Memorizer Panel	207					
Tape Recorder (TTR)	1963					
Depth Encoder (DRE)	1710					
Pressure Wheel (CPW)	1789					
Centralizers: Enter Spring, Standoffs, In-line, o. None — Type	---					
Centralizers: Enter Spring, Standoffs, In-line, o. None — No.	---					
Centralizers: Enter Spring, Standoffs, In-line, o. None — S. O. — Inches	---					
CALIBRATION DATA						

REMARKS:

FIGURE 2

TYPE LOG FDC - CNL w/GR - CALIPER

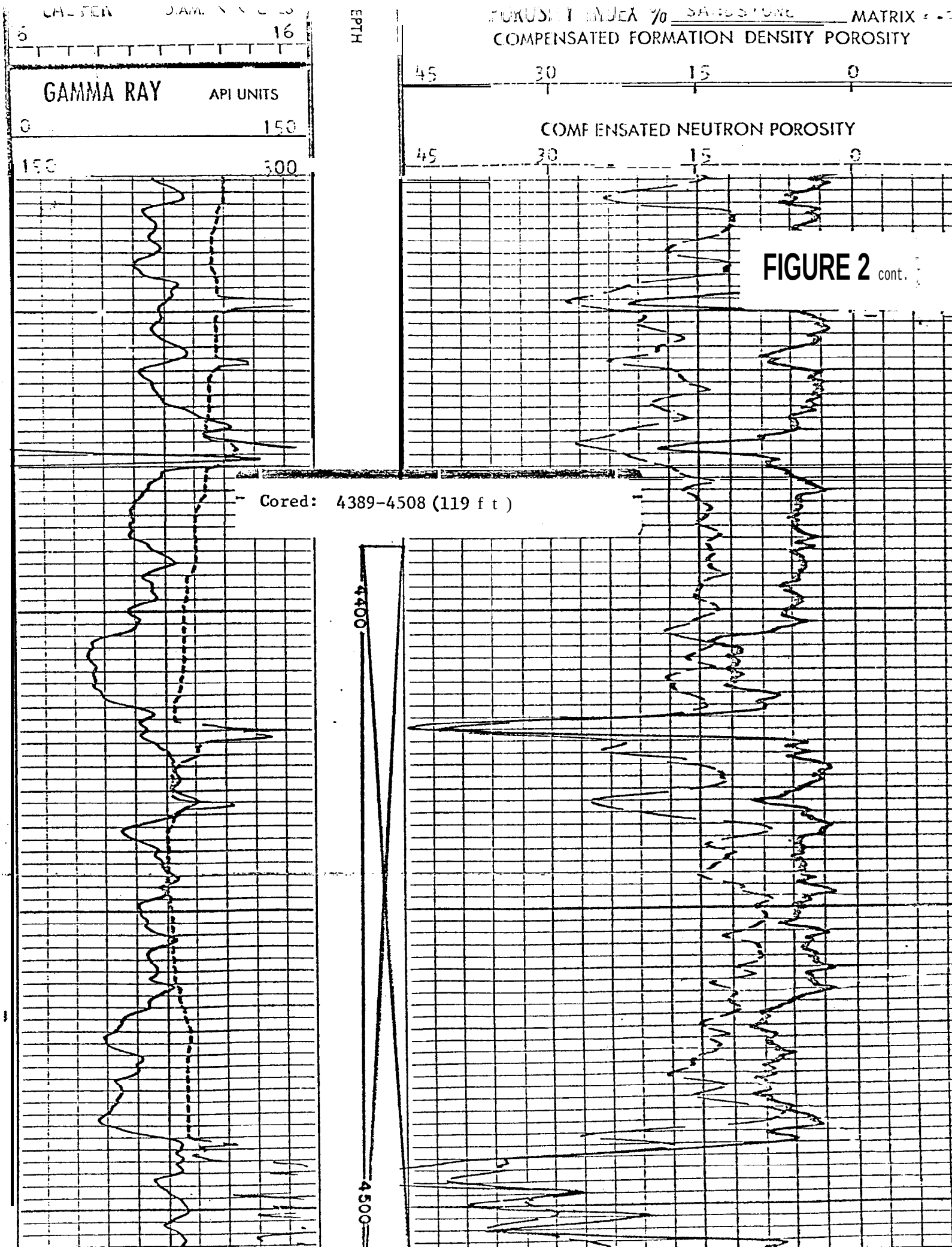
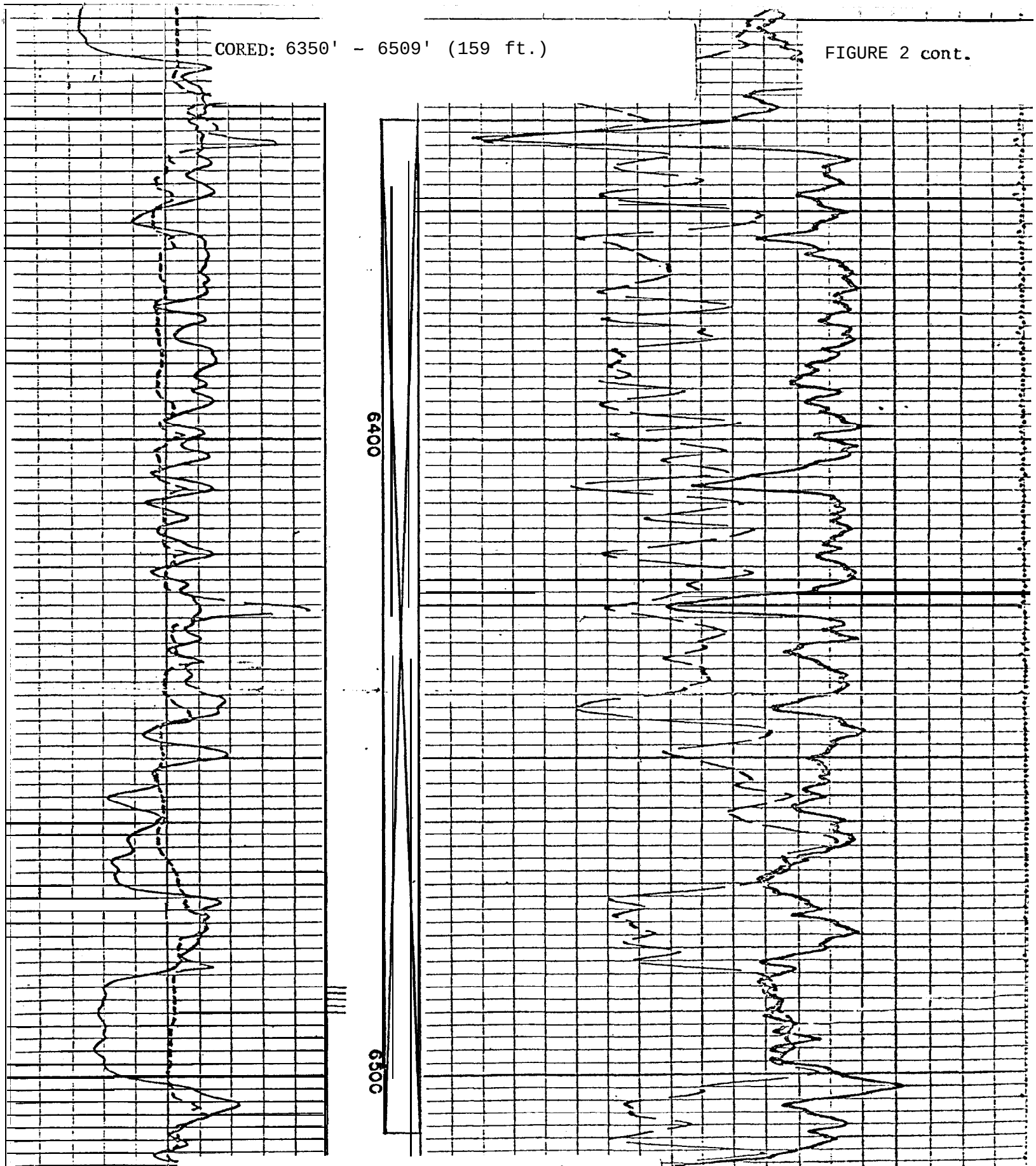


FIGURE 2 cont.

CORED: 6350' - 6509' (159 ft.)

FIGURE 2 cont.



PERFS: 6486' - 87' - 88'- 89' - 90'
TESTS: GTSTM- 0 BWPD
TREATMENT: NONE

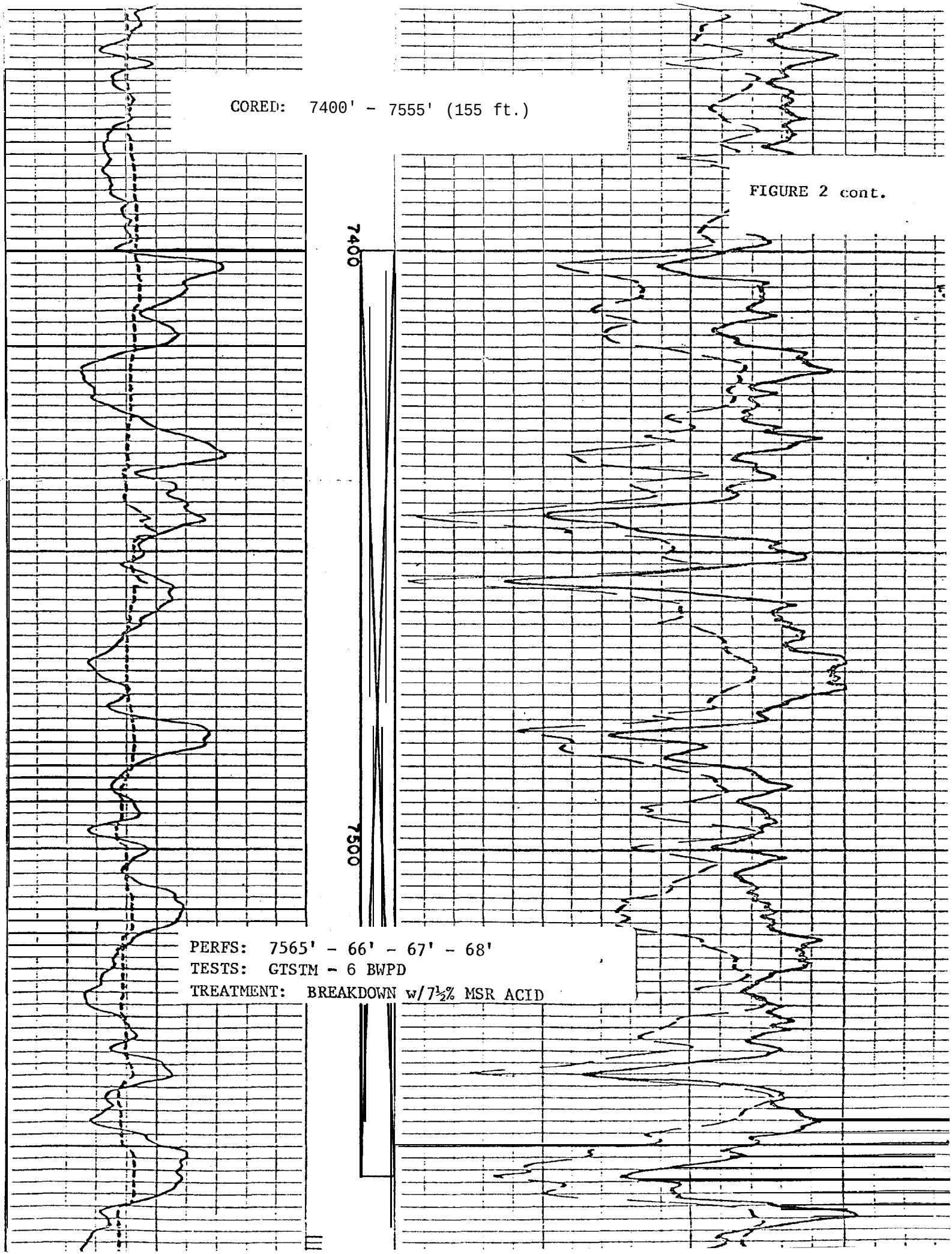


FIGURE 2 cont.

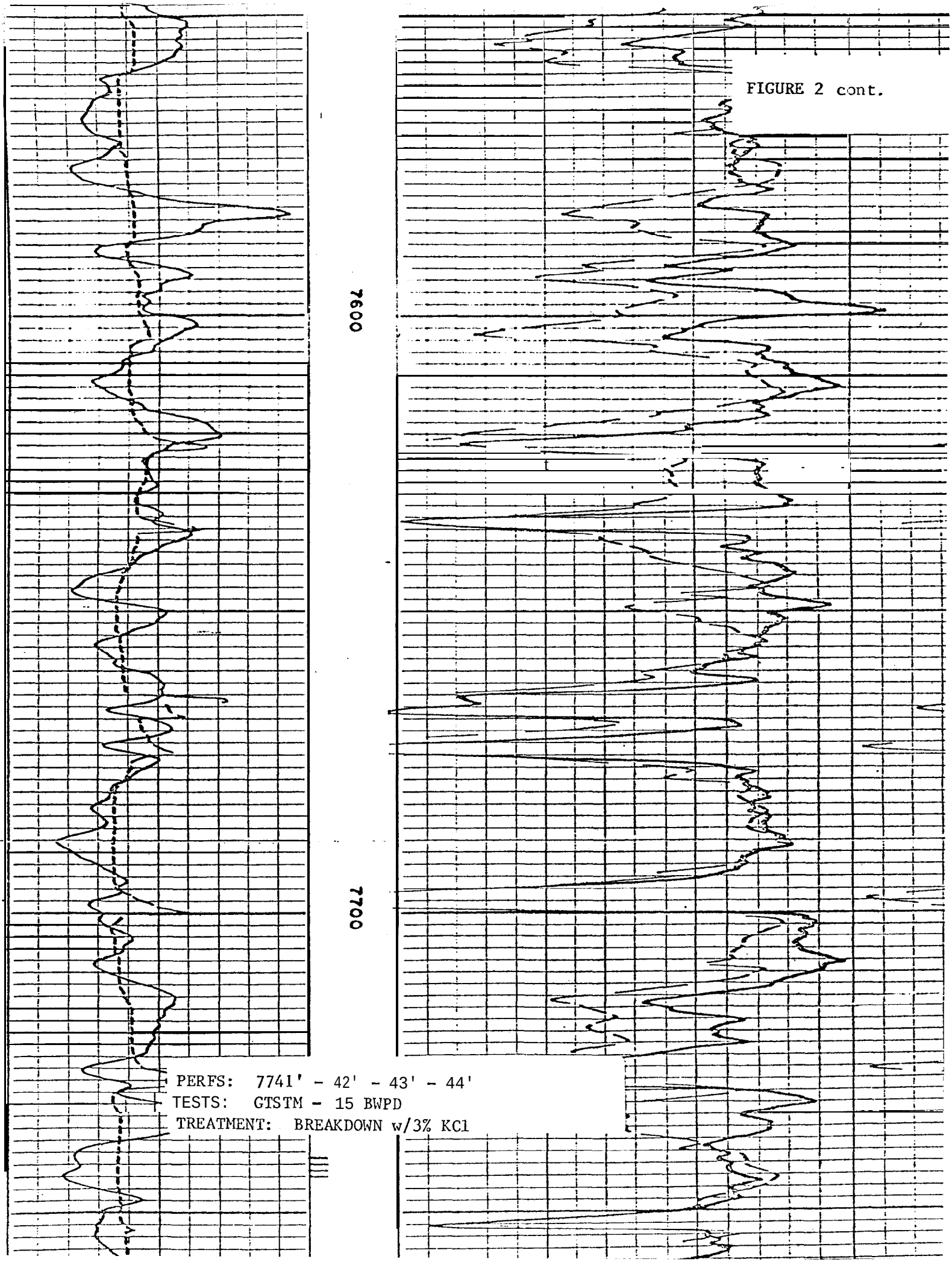


FIGURE 2 cont.

PERFS: 7741' - 42' - 43' - 44'
TESTS: GTSTM - 15 BWPD
TREATMENT: BREAKDOWN w/3% KCl

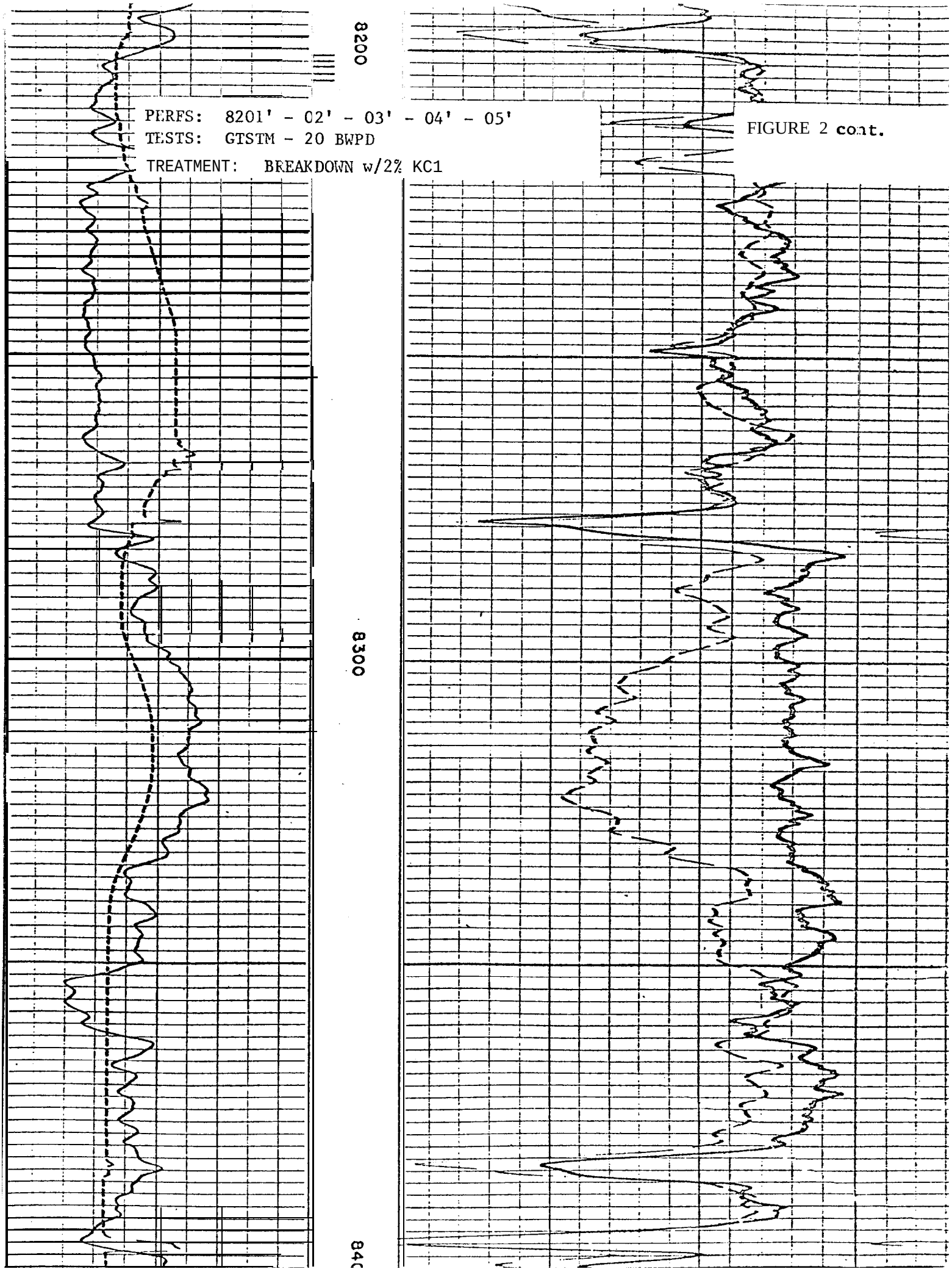


FIGURE 2 cont.

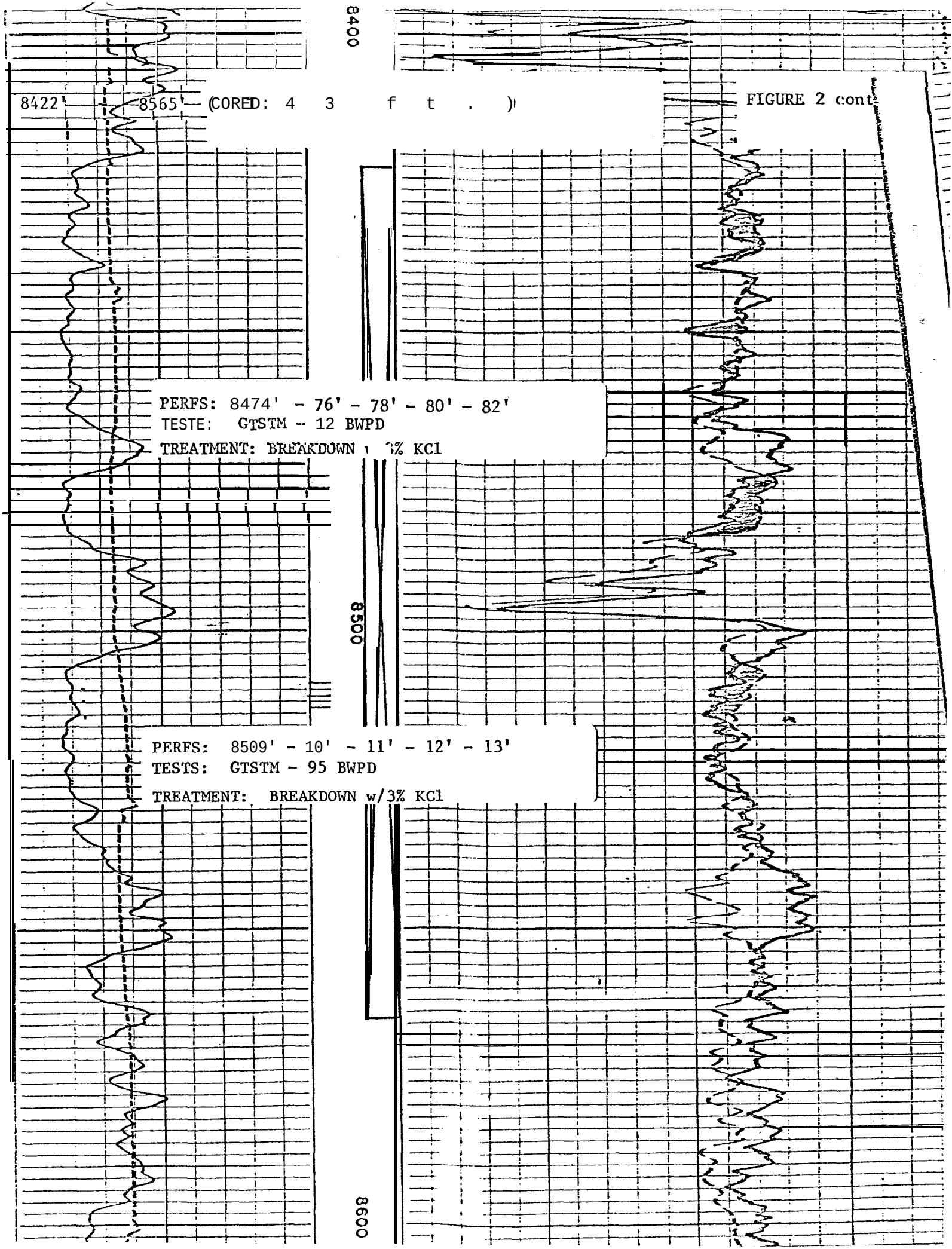
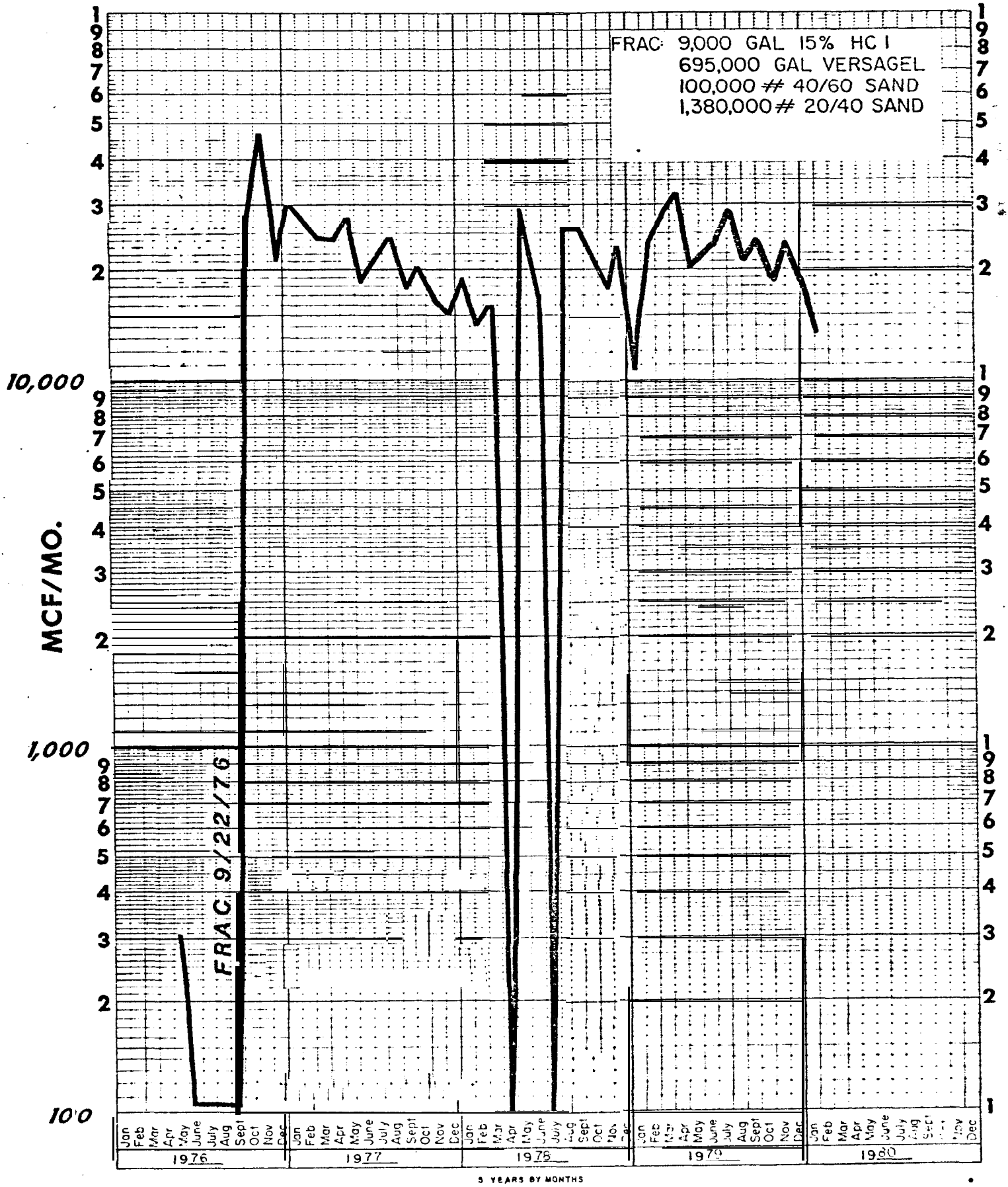
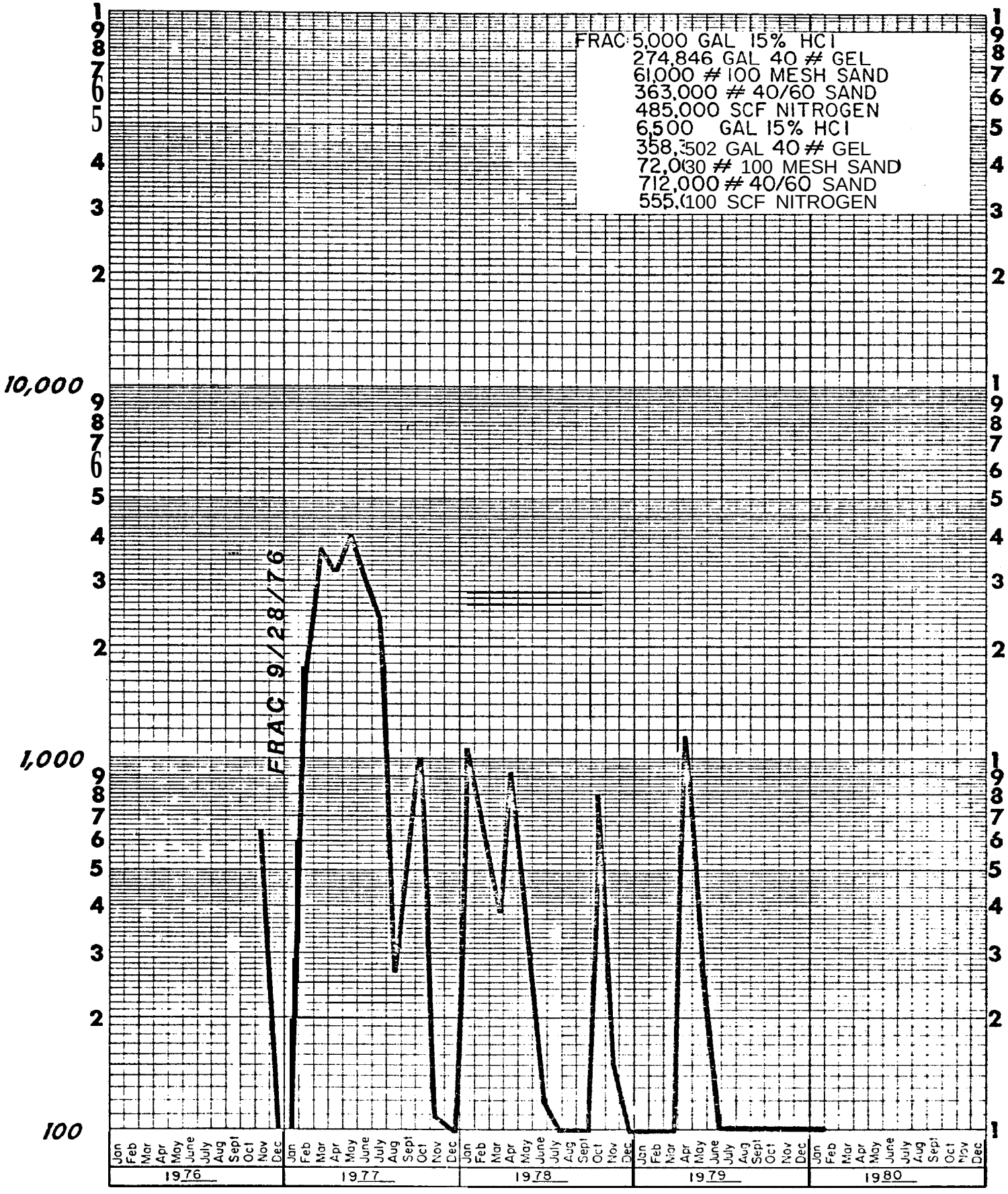


FIGURE 2 cont.

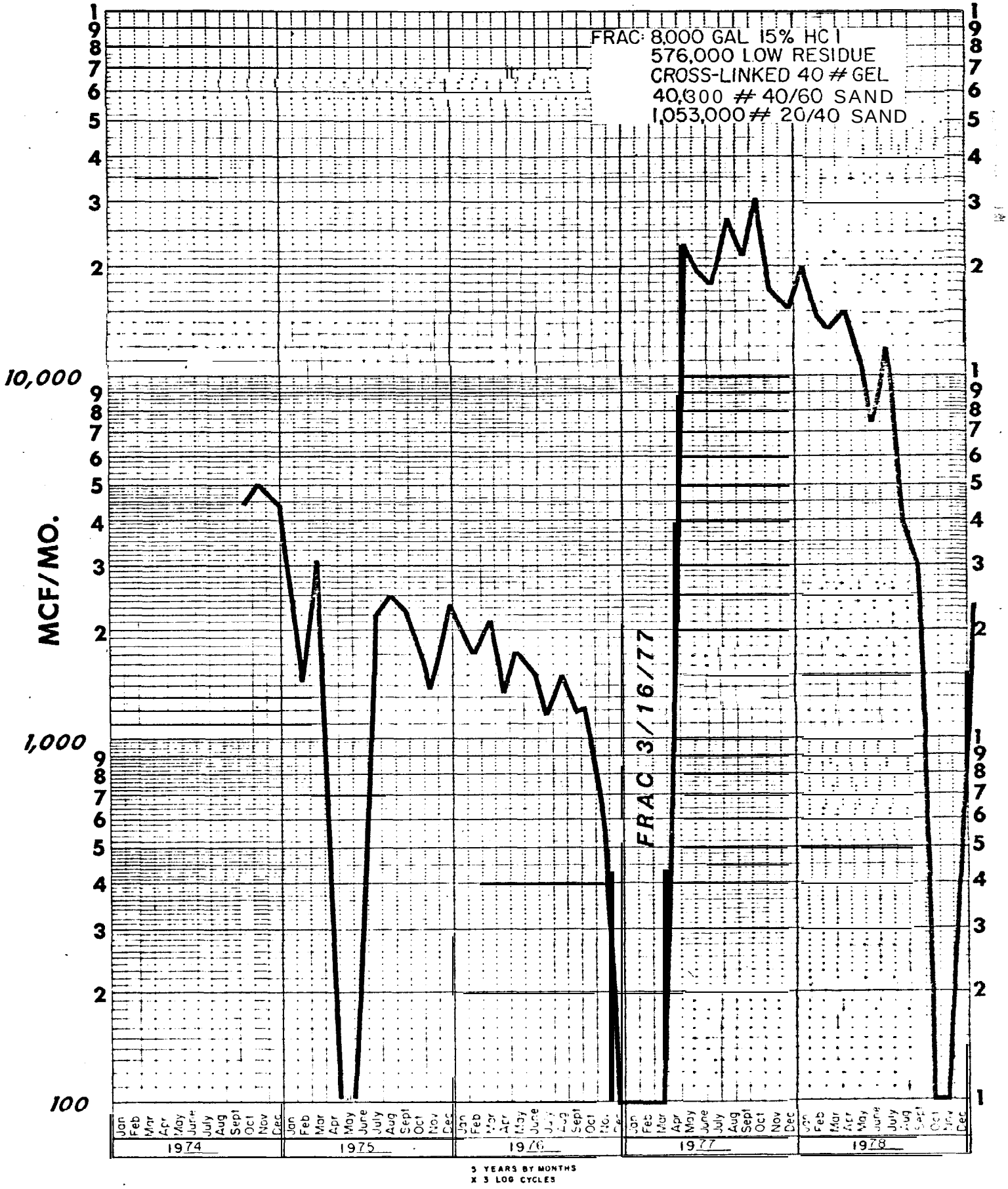
NATURAL BUTTES NO. 18



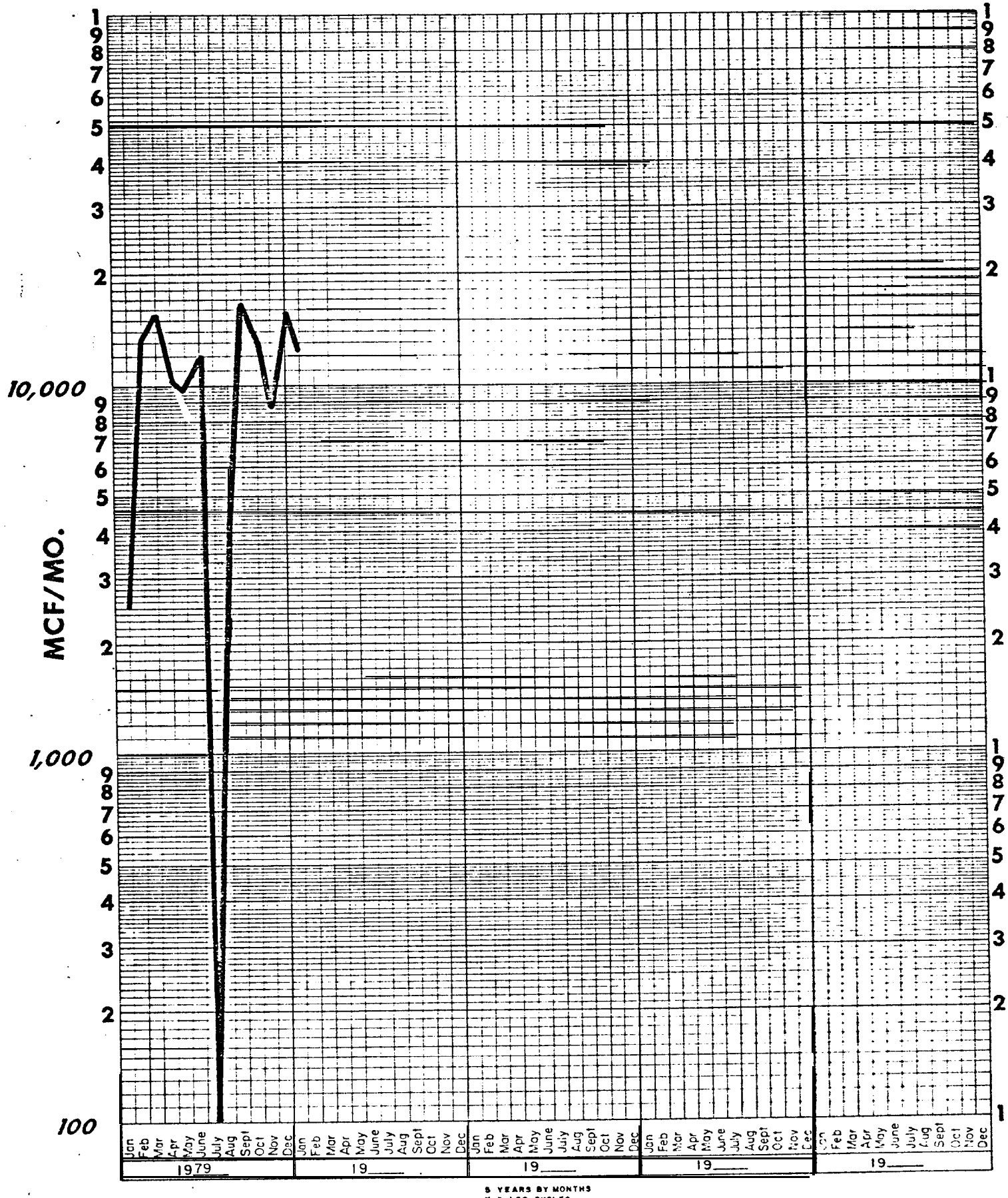
NATURAL BUTTES NO. 19



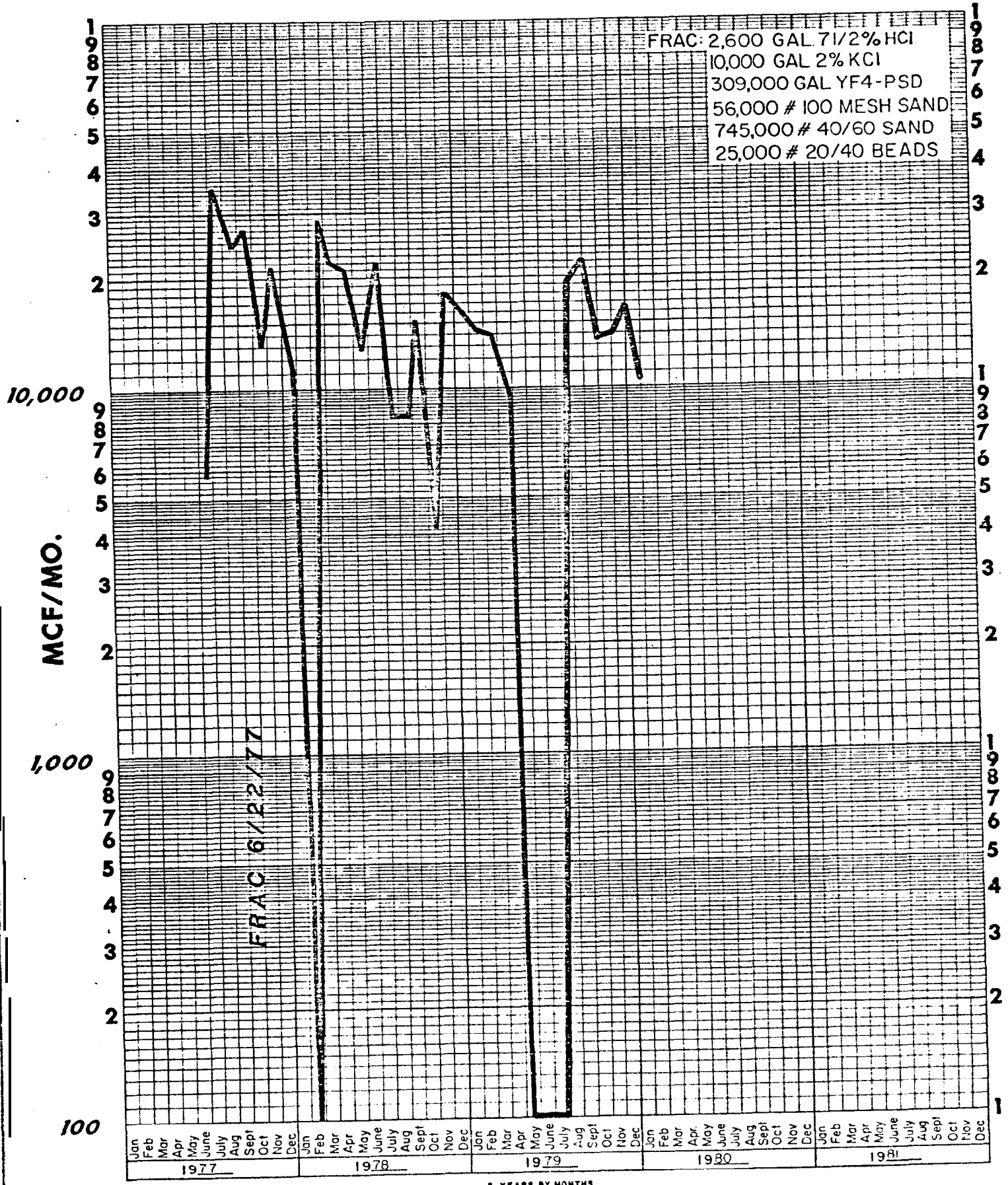
NATURAL BUTTES NO. 14



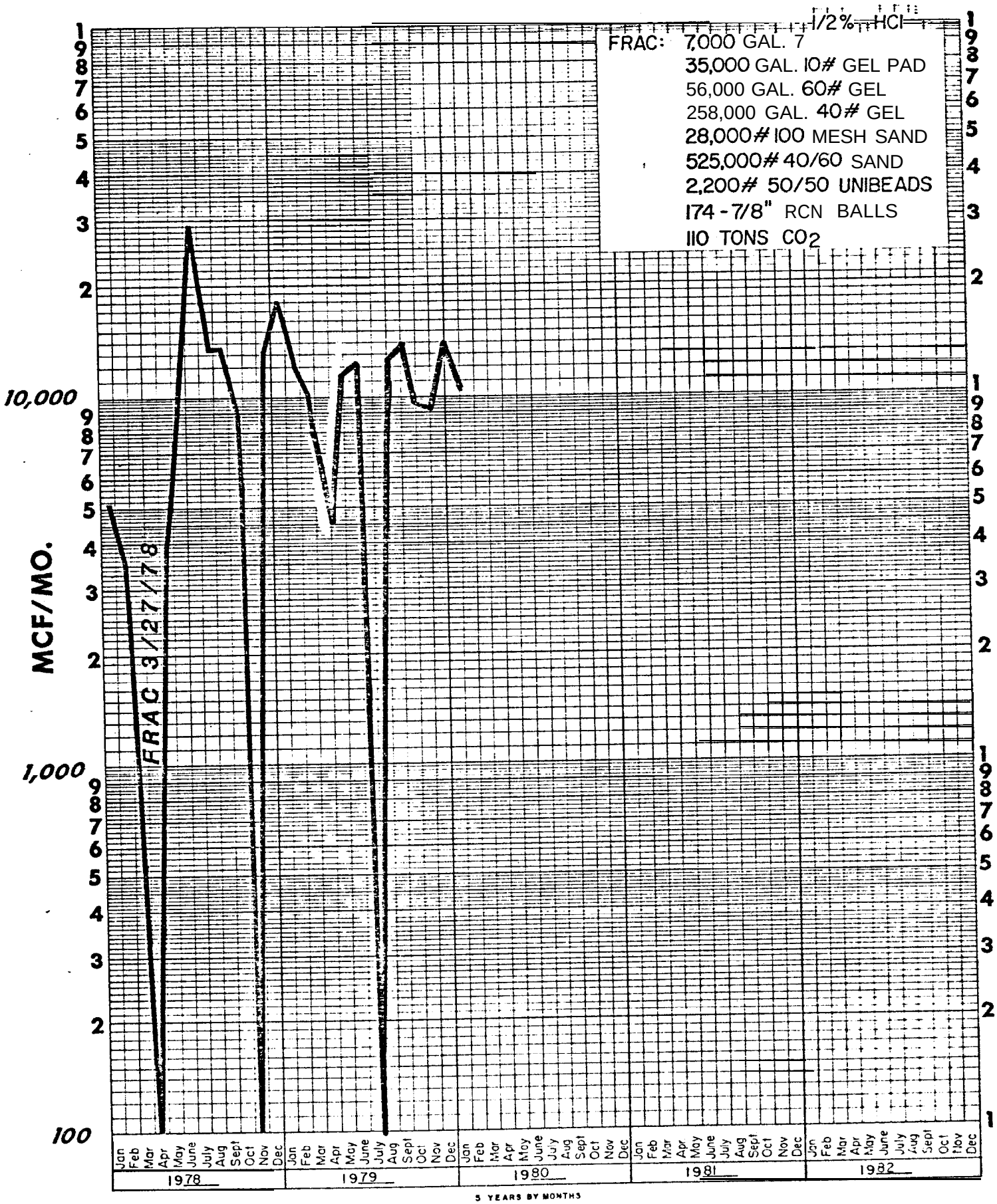
NATURAL BUTTES NO. 14
(CONTINUED)



NATURAL BUTTES NO. 20



NATURAL BUTTES NO. 9



NATURAL BUTTES NO. 22

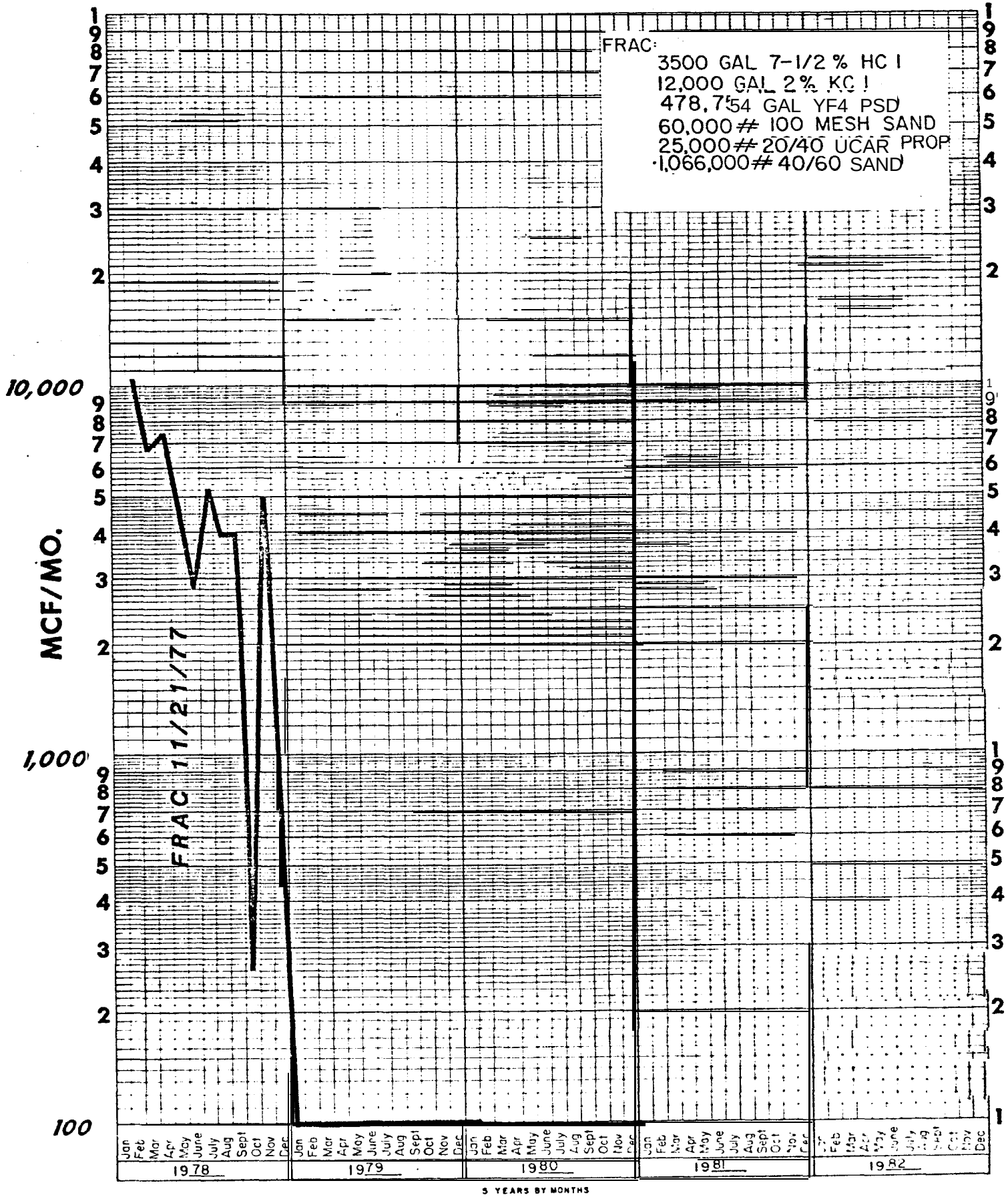
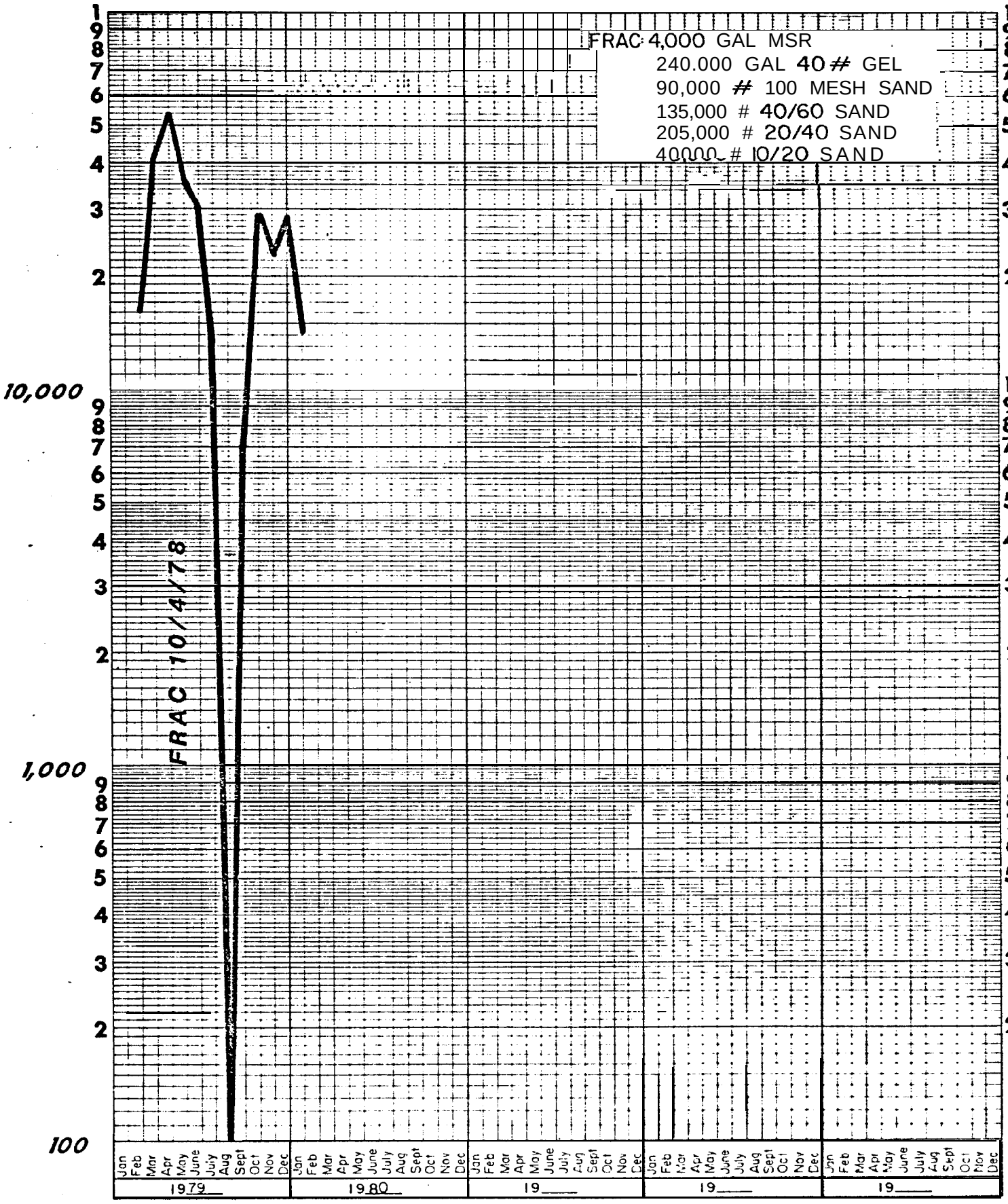


FIGURE 9

CIGE 23-T-10-22



CIGE 2-29-10-21